Final Report

Rocky Mountain Research Station

Effects of Off-Highway Vehicles on Northern Spotted Owls: Sound Data Results

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A Report to the Mendocino National Forest
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EXECUTIVE SUMMARY

The purpose of this pilot study was to record, characterize and quantify motorcycle noise in Northern Spotted Owl (NSO) habitat. This information will be useful in developing a full scale study addressing the effects of motorcycle activity on NSO and in locating new Off-Highway Vehicle (OHV) trails or relocating trails that are too close to spotted owl locations. During the current research project, we recorded the noise level and frequency spectra for recreational motorcycle activity on the Mendocino National Forest (MNF). We measured noise levels at eight locations on the forest over two separate data collection periods during the 2000 field season. In April, we experimentally tested seven different motorcycles (100, 200, 300, 350, 400 {1997 and 1999 models}, and 620 cc) to determine how noise varied based on distance, trail slope and motorcycle type. Motorcycles were experimentally tested at distances of 15, 30, 60, 120 and 400 meters. In November, we passively (i.e., no control over the event) recorded motorcycle noise during an enduro event on the MNF. We selected this forest for study because of its large OHV trail system. NSOs could not be located reliably for testing purposes during the 2000 field season, so we were not able to directly document NSO response to motorcycle activity during this pilot study.

Motorcycle noise recorded at tree microphones was louder and had a greater proportion of noise energy distributed in the middle frequency range than at base microphones, regardless of motorcycle type or distance. In addition, motorcycle noise at tree microphones decreased less than at base microphones as distance increased. We observed that noise level decreased over distance at different rates for different motorcycle types. We also found that motorcycle noise energy decreased less at tree microphones than at base microphones in the middle frequency range as stimulus distance increased. We observed that noise level and frequency spectra varied by motorcycle type. These data suggest that motorcycles with less cubic cm displacement, such as the 200 and 350 cc motorcycles, have greater noise levels and more noise energy in the middle frequency range than motorcycles with higher displacement rates (400 and 620 cc motorcycles) over similar distances. The 200 cc motorcycles had the highest noise levels of the motorcycles

tested on a straight, inclined course, followed by the 350, 300, 400, 620 and 100 cc motorcycles. On a curved, horizontal course, the 350 cc motorcycle had the highest noise level, followed by the 200, 300, 620, 400 and 100 cc motorcycles. We also found that the 200 cc motorcycle had the greatest amount of noise energy in the middle frequency range of all of the motorcycles tested, followed by the 350, 300, 400, 100 and 620 cc motorcycles.

Motorcycle type, trail slope, stimulus distance and owl location are important factors that need to be considered when studying noise impacts on spotted owls. The following points are offered as a list of recommendations to be examined more closely in conducting future noise research:

1) Distance and Noise Threshold: We do not anticipate that NSOs would flush in response to motorcycle activity > 180 m from an owl's location based on prior noise research conducted on Mexican Spotted Owls (MSO) with chainsaw noise. At distances < 180 m, motorcycle noise levels did surpass the flush threshold established for MSOs. Further research is needed to experimentally test NSO response to motorcycle activity to better develop this distance and noise threshold relationship;
2) Trail slope and shape: Our data indicate that motorcycles passing by on steep (>16° slope) inclined trails may elicit the greatest behavioral response by spotted owls, followed by motorcycles on horizontal (0° slope) and moderately (9-16° slope) inclined trails. Traffic on straight trails may also elicit greater spotted owl response behavior than curved trails;
3) Microphone Placement: Motorcycle noise levels at microphones placed in trees 10 m above ground level were louder and lost less noise energy over distance than microphones placed at the base of the same trees. Owls at nest or roost locations could receive substantially higher noise levels than those recorded at base microphones. We recommend that researchers record motorcycle events at actual owl nest or roost locations before or after the nesting season to determine the exact noise levels. These data could be used to extrapolate nest data from base microphones to tree locations;
4) Nest type: Cavity nests may receive higher noise levels than other external structure nest

types due to a resonating effect within the cavity itself;

5) Motorcycle type: Motorcycles with higher frequency noise signatures (e.g., 200 cc motorcycles) are potentially more disturbing to spotted owls than lower frequency motorcycles types (e.g., 400 cc motorcycles);
6) Driver aggressiveness: Driver aggressiveness in riding a course can have a substantial effect on motorcycle noise level and noise energy distribution;
7) Motorcycle use: We recommend that enduro check points and fuel stops not be located near owl locations because of the potential increases in noise level and duration associated with such activity.

ACKNOWLEDGMENTS

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BACKGROUND

The purpose of this report is to characterize motorcycle noise on the Mendocino National Forest (MNF) and relate these findings to possible effects on the threatened Northern Spotted Owl (*Strix occidentalis caurina*, NSO). Information from this project and any future work could be used to determine the effects of motorcycle activity on NSOs, help determine locations of new trails and provide information on which Off-Highway Vehicle (OHV) trails might need to be relocated. The U.S. Fish and Wildlife Service (USFWS) listed the entire spotted owl species as a Category-2 candidate on 6 January 1989 Notice of Review (54FR 554). Category-2 candidates are those species that the USFWS believes may qualify for listing as threatened or endangered but for which insufficient information is available to support the required ruling. The northern subspecies was listed as threatened in 1990. Currently there are little data available on the effects of noise on spotted owls (Delaney et al. 1999), especially vehicle noise.

The Endangered Species Act mandates all federal agencies to conserve threatened and endangered species (TES) and to evaluate the impacts of their activities on listed species (Scott et al. 1994). Because noise management has traditionally focused mainly on minimizing human annoyance, loud activities have often been relocated to sparsely populated areas where wildlife reside. This research was conducted jointly by the U.S. Forest Service, MNF (Region 5), Rocky Mountain Research Station (RMS) and the U.S. Fish and Wildlife Service (USFWS Region 1). The U.S. Forest Service and the USFWS funded their respective participation in this study.

OBJECTIVES

The primary objective of this study was to record, characterize and quantify motorcycle noise in NSO habitat. Secondarily, we propose that these data could be used to develop a framework for a full scale study addressing the effects of motorcycle noise on NSOs.

SCOPE

The scope of this initial project relates to motorcycle noise on the MNF in California. All aspects of the research plan were reviewed and approved by the USFWS Region 1 and the MNF before noise testing began. Results from this project apply directly to the MNF, but may also be applicable to other national forests where similar noise events occur. Noise sources examined during this project include motorcycle OHVs during several controlled, experimental events and one enduro on the MNF.

LITERATURE REVIEW

Noise disturbance studies have often been anecdotal and fail to quantitatively measure either the stimulus or the behavioral response related to the animal's fitness. Predictive models for the relationship between disturbance dosage and quantifiable effects are even more scarce (Awbrey and Bowles 1990; Grubb and King 1991; Grubb and Bowerman 1997). Although many types of human disturbance have been reported as affecting birds of prey (Fyfe and Olendorff 1976), very little research has addressed the effects of human activity on spotted owls (Delaney et al. 1999, Swarthout and Steidl 2001), especially the threatened NSO.

Few researchers have directly compared differences in bird responsiveness between aerial and ground-based disturbances (Bowles et al. 1990, Grubb and King 1991). Studies that have examined the effects of aircraft activity on nesting birds (e.g., Platt 1977; Windsor 1977; Ellis 1981; Anderson et al. 1989; Delaney et al. 1999) have often noted a slight but nonsignificant decrease in nesting success and productivity for disturbed versus undisturbed nests. Anderson et al. (1989) noted a slight decline in the nesting success of experimental Red-tailed Hawk (*Buteo jamaicensis*) nests versus control nests after helicopter disturbances (80% experimental versus 86% control). In contrast, ground-based disturbances appear to have a greater effect than aerial disturbances on the nesting success of some bird species. In their classification tree model of Bald Eagle (*Haliaeetus leucocephalus*) responses to various anthropogenic disturbances, Grubb

and King (1991) determined that Bald Eagles in Arizona showed the highest response frequency and severity of response toward ground-based disturbances, followed by aquatic, and lastly by aerial disturbances. Delaney et al. (1999) reported similar findings for Mexican Spotted Owl (MSO; *Strix occidentalis lucida*) response to military helicopter activity and chain saws, observing that chain saws elicited a greater flush response rate than helicopters at comparable distances and noise levels.

A bird's behavior during the nesting season is an important determinant of its ultimate nesting success or failure (Hohman 1986). Various bird species have been reported to abandon their nests after being exposed to ground-based and aerial disturbances. White and Thurow (1985) reported that 8 of 24 Ferruginous Hawks (*Buteo regalis*) nests were abandoned after being exposed to various ground-based disturbances, but Anderson et al. (1989) found only 2 of 29 Red-tailed Hawk nests were abandoned after being flushed by helicopter flights. Ellis et al. (1991) found only 1 of 19 Prairie Falcon (*Falco mexicanus*) nests were abandoned when exposed to frequent low-altitude jet flights during the nesting season. Platt (1977) and Windsor (1977) reported no impact directly related to low-level jet flights over 11 Gyrfaclon (*F. rusticolus*) nests and helicopters over 6 Peregrine Falcon (*F. Peregrinus*), respectively.

Birds may be more susceptible to disturbance-caused nest abandonment early in the nesting season because parents have less time and energy invested in the nesting process (Knight and Temple 1986). Some birds appear reluctant to leave the nest later in the nesting season (Anderson et al. 1989; Ellis et al. 1991; Delaney et al. 1999). Steenhof and Kochert (1982) reported that Golden Eagles (*Aquila chrysaetos*) and Red-tailed Hawks exposed to human intrusions during early incubation had significantly lower nesting success than individuals exposed later in the season (45% success for Golden Eagles and 57% for Red-tailed Hawks within experimental groups versus 71% and 74% success with control groups, respectively). Although reactions of adult birds at the nest can influence hatching rates and fledgling success (Windsor 1977), flush behavior of adult birds from the nest is poorly quantified (Fraser et al. 1985; Holthuijzen et al. 1990). In the few studies that have examined bird responses to specific

disturbance types (e.g., aircraft approach distance), flush rates were higher if birds were naive (i.e., not previously exposed; Platt 1977). Some birds are more reluctant to flush off the nest during incubation and early nestling phases than later in the season (Grubb and Bowerman 1997; Delaney et al. 1999). Bird responsiveness has been shown to increase as the nesting season progresses (Grubb and Bowerman 1997). Delaney et al. (1999) found that MSOs flushed more frequently in response to helicopters later in the reproductive cycle during the post-fledgling phase and suggested that adult defensive behavior may decrease as the young mature. In contrast, Holthuijzen et al. (1990) found Prairie Falcon responsiveness to nearby blasting activity decreased as the nesting season progressed.

Few studies have documented the threshold distance beyond which birds flush in response to noise disturbance events. In those studies that reported stimulus distance, it was rare for birds to flush when the stimulus distance was greater than 60 m (Carrier and Melquist 1976; Edwards et al. 1979; Craig and Craig 1984; Delaney et al. 1999). Similar findings were reported by Carrier and Melquist (1976) for Osprey (*Pandion haliaetus*), and Ellis (1981) for Peregrine Falcons. Many disturbance studies suggest that animal response increases with decreasing stimulus distance (Platt 1977; Grubb and King 1991; McGarigal et al. 1991; Stalmaster and Kaiser 1997), though only a few studies have experimentally tested this relationship (Delaney et al. 1999). Delaney et al. (1999) found that the proportion of owls flushing in response to a disturbance was strongly and negatively related to stimulus distance and positively related to noise level. Spotted owls were not observed flushing when noise stimuli were > 105 m from owl locations during the post-fledgling period, nor during experimental testing during the nesting phase. Owls were only observed to flush during the post-fledgling phase.

Even fewer examples are available for noise response thresholds. Snyder et al. (1978) reported that Snail Kites (*Rostrhamus sociabilis*) did not flush even when noise levels were up to 105 decibels, A-weighted (dBA) from commercial jet traffic. This result was qualified by the fact that test birds were living near airports and may have habituated to the noise. Edwards et al. (1979) found a dose-response relationship for flush responses of several species of gallinaceous

birds when approach distances were between 30 and 60 m and noise levels approximated 95 dBA. Delaney et al. (1999) reported that MSOs did not flush during the nesting season when the Noise Exposure Level (SEL; total noise energy over time) for helicopters was ≤ 102 dBO (owl-weighted; 92 dBA) and the Equivalent Average Noise Level (LEQ; average noise level over time) for chain saws was ≤ 59 dBO (46 dBA). It is important to note that noise from chainsaw and helicopter events were only recorded at the base of nest or roost trees. No recordings were made at nest or roost height and therefore these noise levels are conservative levels compared to what owls were actually receiving, which was almost certainly greater.

Distance has been described as the most commonly used surrogate for noise disturbance in the literature on animal response to noise, and has been proposed to be the best representative for quantifying the relationship between stimulus and response measures (Awbrey and Bowles 1990). The reason appears to be that distance is more conveniently implemented into management practices (i.e., establishing spatial buffer zones) than other variables.

TECHNICAL APPROACH

Study Area

The MNF is located on the eastern spur of the Coastal Mountain Range in northwestern California and covers approximately 3620 square km (Figure 1). The forest receives a variety of multiple uses such as recreational activity (e.g., enduro motorcycle events), grazing and logging. Elevations in the forest range from 229 m in the Grindstone Creek Canyon in the Sacramento Valley Foothills on the MNF's eastern edge, to 2466 m on South Yolla Bolly Mountain in the northern part of the forest. The average elevation is about 1219 m. This study took place on the Grindstone Ranger District in Colusa Country, southwest of Stonyford, in the southeastern portion of the MNF (Figure 2).

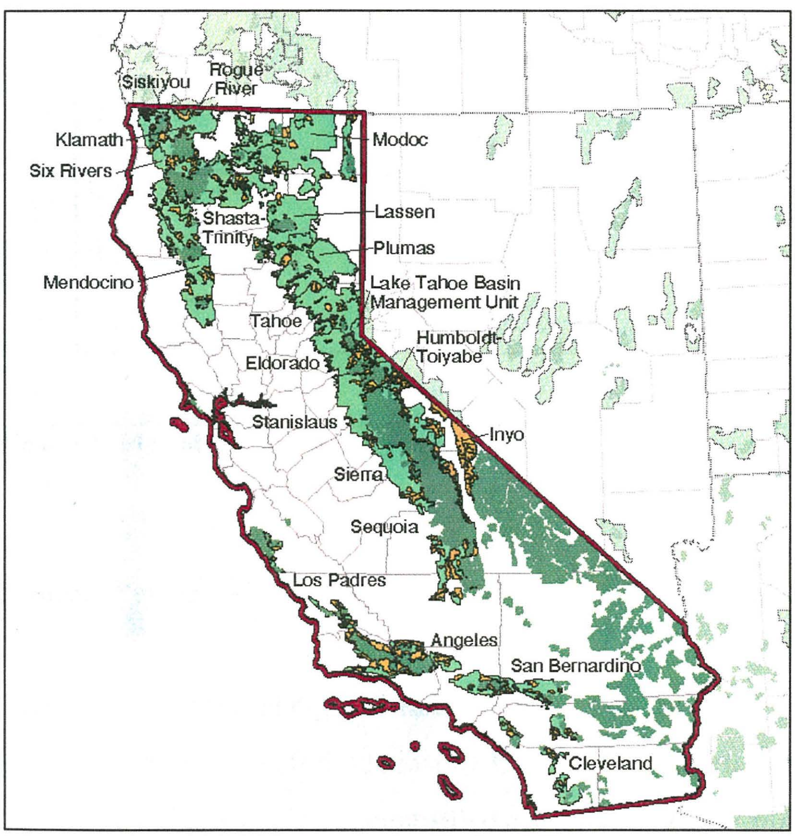

Figure 1. Location of the Mendocino National Forest in northwestern California.

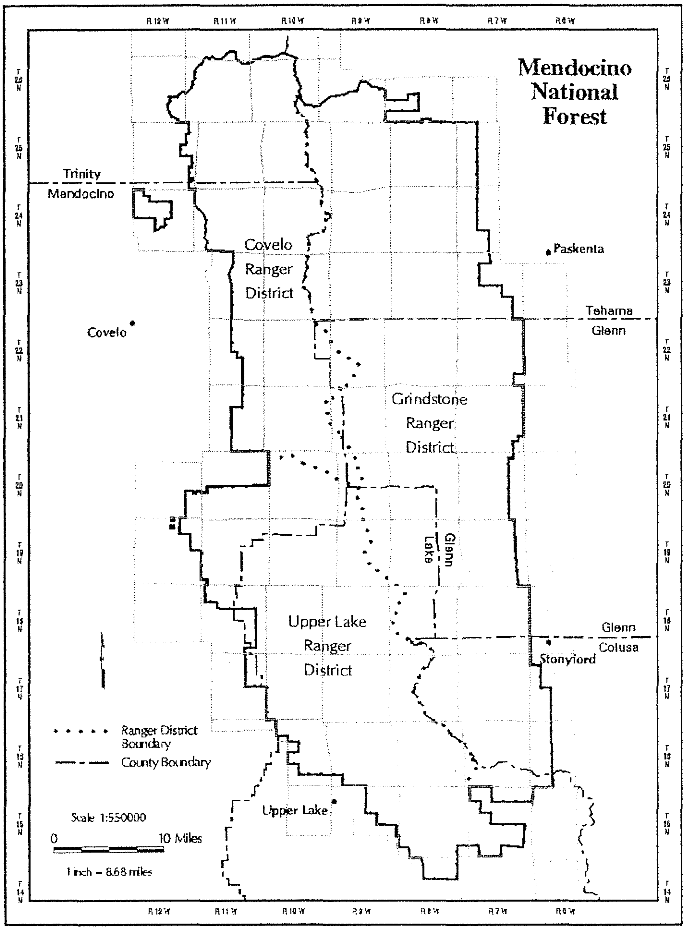

Figure 2. Map of the Mendocino National Forest.

Sample Period

We measured noise at eight different locations on the MNF over two separate data collection periods during the 2000 field season. On 24 and 25 April, we tested seven different motorcycles (Table 1) under realistic but controlled conditions to determine how noise varied based on distance, slope and motorcycle type. The same riders rode the 300 and 400 cc (1999 model)

Table 1. Motorcycles used during preliminary noise testing on the Mendocino National Forest on 24-25 April 2000. Motorcycles with the symbol * were tested on 24 April, while those with a + symbol were tested on 25 April 2000. Those motorcycles with the symbol • were tested on both days.

Year	Make	Exhaust System/Misc.
1999•	KTM	300 cc, 2 stroke EXC FMF exhaust pipe, FMF turbine cove II spark arrestor
1999•	Honda	400 cc, 4 stroke XR stock Honda exhaust and baffle
1997+	Honda	400 cc, 4 stroke XR stock exhaust with aftermarket vortip baffle
1997*	KTM	200 cc, 2 stroke MXC stock Kriszman exhaust/arrestor
1996*	KTM	620 cc, RXC Street Legal, stock exhaust
1993*	Honda	100 cc, 4 stroke XR stock exhaust
1991*	Suzuki	350 cc, 4 stroke DR with 7 disk supertrapp spark arrestor

motorcycles on 24-25 April. The rider of the 620 cc motorcycle on 24 April rode the 400 cc motorcycle (1997 model) on 25 April. Motorcycles were experimentally tested at distances of 15, 30 and 60 m on 24 April and 15, 30, 60, 120, and 400 m on 25 April. On 19 November, we passively (i.e., no control over the event) recorded an enduro event on the MNF. We selected four different locations along the 96.6 km course (60-mile), with each site representing a different slope and/or distance situation. There were 198 riders in this event using a wide range of motorcycle makes and models (motorcycle make and model information was not recorded). NSOs could not be located reliably for testing purposes during the 2000 field season, so we were not able to directly document NSO response to motorcycle activity during this study.

Test Site Selection

Eight sample test sites were selected based on (1) slope; (2) distance; (3) habitat type; and (4) proximity to existing motorcycle trails within the MNF. We attempted to select sites that were in close proximity to historic NSO territories and would be representative of habitat characteristics that owls would use during the nesting season. Four different locations (sites 1-4) were tested during the first data collection period in April (Table 2). Four additional locations (sites 5-8) were tested during a second data collection period in November. Trails were

Table 2. Description of test sites selected for motorcycle testing on the Mendocino National Forest on 24-25 April 2000.

Date	Location	Site Number	Trail Shape	Slope (degrees)	Microphone Position	Distance (m)
24 April 2000	M5/M30 junction	1	straight trail	14-16	horizontal	15
24 April 2000	M5/M30 junction	1	straight trail	14-16	horizontal	30
24 April 2000	M5/M30 junction	1	straight trail	14-16	horizontal	60
24 April 2000	M5/M20 junction	2	curved trail	0	horizontal	15
24 April 2000	M5/M20 junction	2	curved trail	0	horizontal	30
24 April 2000	M5/M20 junction	2	curved trail	0	horizontal	60
24 April 2000	M5/Big Sullivan junction	3	straight trail	6-8	downslope	30
24 April 2000	M5/Big Sullivan junction	3	straight trail	6-8	downslope	60
24 April 2000	M5/Big Sullivan junction	3	straight trail	6-8	downslope	120
24 April 2000	M5/Big Sullivan junction	3	straight trail	6-8	downslope	400
24 April 2000	Miner Ridge Road	4	straight trail	0	upslope	30
24 April 2000	Miner Ridge Road	4	straight trail	0	upslope	60
24 April 2000	Miner Ridge Road	4	straight trail	0	upslope	120
24 April 2000	Miner Ridge Road	4	straight trail	0	upslope	400
19 November 2000	M10/M34 junction	5	curved trail	9-12	horizontal	10-30
19 November 2000	M34/17N63 junction	6	straight trail	0	horizontal	60
19 November 2000	M36/17N63 junction	7	straight trail	18-20	horizontal	90
19 November 2000	M36/17N63 junction	7	straight trail	18-20	horizontal	120
19 November 2000	M36/17N63 junction	7	straight trail	18-20	horizontal	180
19 November 2000	M12/17N12 junction	8	straight trail	9-14	horizontal	30
19 November 2000	M12/17N12 junction	8	straight trail	9-14	horizontal	60
19 November 2000	M12/17N12 junction	8	straight trail	9-14	horizontal	90

designated as having no incline (0°), a slight (1-8° slope), moderate (9-16° slope), or steep (> 16° slope) incline and either a curved or straight course. We used 60 m as a realistic minimum distance for discussing the possible effects of motorcycle activity near spotted owl locations based on observed trail locations and historic owl sightings within the Grindstone Ranger District. Distances < 60 m would represent extreme noise events that we predict will have a low frequency of occurrence near NSOs on the MNF.

Noise Instrumentation and Recording

Sony TCD-D8, Digital Audio Tape (DAT) recorders were used to continuously record all noise

events, along with exact time and date. We attached Bruel & Kjaer (B&K) Type 4149, 1.3-cm Condenser Microphones with 7.5-cm wind screens, to B&K Model 2639 Preamplifiers, mounting the microphone on a 1-m stick, and placing the unit 1 m from the tree trunk (sites 1-5; Table 1). We also placed microphones 10-m up trees to simulate spotted owl roost and nest locations (sites 1-8; Table 1). A 1.0 kHz 94dB calibration signal from a B&K Type 4250 Noise Level Calibrating System was recorded before and after each recorded data session. This signal provided an absolute standardized reference point for noise and spectra for data reduction using a B&K Type 2144 Frequency Analyzer and/or a Rion NA-27 Precision Integrating Noise Level Meter.

Noise Metrics

Noise is defined as sound which is undesired or which constitutes an unwarranted disturbance, and can alter animal behavior or normal functioning (ANSI S1.1-1994). Appropriate noise metrics and frequency weighting are essential to adequately quantify impact for each type of noise. A noise metric is chosen to measure noise dose in a way that meaningfully correlates with subject response. Frequency weighting is an algorithm of frequency-dependent attenuation that simulates the hearing sensitivity and range of the study subjects. Frequency weighting discriminates against noise that, while easily measured, is not heard by the subjects. Flat-weighting (or absence of any weighting function) does not emphasize any portion of the frequency spectrum and therefore represents the true noise level and frequency for a stimulus event (Figure 3).

The commonly used A-frequency weighting attenuates noise energy according to human hearing range and sensitivity (ANSI S1.40-1983) and generally will not be appropriate for animals species. However, it is useful to present A-weighted noise levels (dBA) because they occur on noise-level meters and are widely used. Because both flat- (dBF) and A-weighting do not accurately reflect the way a spotted owl hears noise, we developed a preliminary estimate for an owl-weighting curve based on information in the literature (dBO; Delaney et al. 1999).

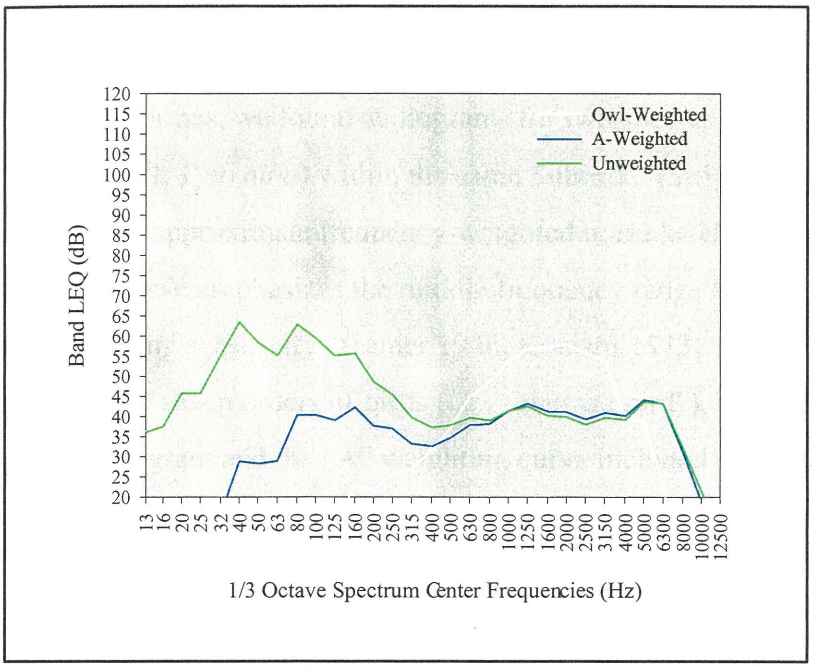

Figure 3. A comparison of owl-, A- and unweighted equivalent maximum noise energy levels (LEQs) for a 60-m motorcycle pass on 24 April 2000.

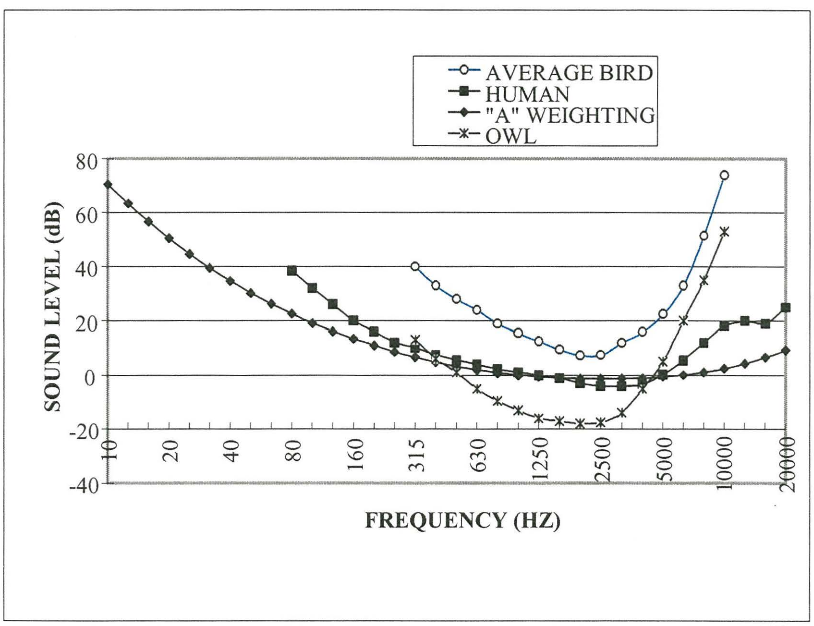

Figure 4. Examples of audiograms and frequency weighting.

An audiogram describes hearing range and sensitivity and provides information on which a frequency weighting algorithm can be based for a specific species. Available information indicates that owl hearing is quite similar among members of a taxonomic order. Within the order Strigiformes, we found audiograms for two species (Great-horned Owl, *Bubo virginianus*, and Barn Owl, *Tyto alba*) within the same Suborder (Strigi) as spotted owls. These audiograms were used to approximate frequency-weighted noise levels for spotted owls (Figure 3). This owl-weighting curve emphasizes the middle frequency range (1-4kHz) where test owls had the highest hearing sensitivity (Trainer 1946, Konishi 1973). Figure 4 shows a composite average audiogram of seven orders of birds (i.e., "average bird"), with an approximate representation of a human audiogram and the "A" weighting curve included for comparison. The "owl" audiogram further illustrates how audiograms can vary among taxonomic groups.

The current project requires specialized metrics and techniques to meaningfully measure and relate noise impacts on animals. We measured noise events in terms of unweighted one-third-octave-band levels, applied frequency weighting to the resultant spectra, and then calculated the appropriate overall metric. We used 1-sec maximum equivalent energy level ($LEQ_{max.\ 1\text{-}sec}$) for measuring motorcycle noise during this study. This metric represents the maximum 1-sec of noise energy recorded during each motorcycle pass. Motorcycle noise is also presented at L_{01}, L_{10}, L_{50} and maximum levels. "L" levels represent the noise level that motorcycles surpassed for a specific period of time, e.g., L_{01} = noise level exceeded 1% of the time, etc. L_{10} represents the peak noise level, while L_{50} represents an average or mean noise level for the entire event. Maximum levels represent the highest noise level recorded along specific points during the enduro event. Ambient sound was measured as LEQ (EPA 1982) and compared with motorcycle noise levels.

RESULTS

Microphone Placement

Motorcycle noise recorded at tree microphones was louder than at base microphones, regardless of motorcycle type or distance (Table A-1, Appendix A). For example, a 200 cc motorcycle registered 98.0 dBO (88.2 dBA) at 15 m from a tree microphone compared with 94.4 dBO (84.5 dBA) from a base microphone. A similar pattern was recorded for a 350 cc motorcycle that registered 90.2 dBO (78.6 dBA) at 15 m from a tree microphone compared with 86.5 dBO (74.8 dBA) from a base microphone (Road M5/M20 heliport: inclined course with horizontal microphone placement). In addition, motorcycle noise at tree microphones decreased less than at base microphones as distance increased. At 60-m, the 200 cc motorcycle registered 84.5 dBO (72.5 dBA) at a tree microphone versus 67.4 dBO (56.1 dBA) at a base microphone, which equaled to a 27.0 dBO (28.4 dBA) decrease for the base microphone from 15-60 m and only a 13.5 dBO (15.7 dBA) decrease for the tree microphone over this same distance. We also observed that noise level decreased over distance at different rates for different motorcycle types. As compared with the 200 cc motorcycle, the 350 cc motorcycle registered 82.5 dBO (69.8 dBA) at a tree microphone versus 67.1 dBO (54.5 dBA) at a base microphone, which equated to a 19.4 dBO (20.3 dBA) decrease for the base microphone and only a 7.7 dBO (8.8 dBA) decrease for the tree microphone over this distance (Table A-1, Appendix A).

Tree microphones recorded a greater proportion of motorcycle noise energy in the middle frequency range than base microphones, regardless of motorcycle type or distance (also see Motorcycle Comparisons section below). In examples presented in Figures B-1, B-3 and B-5 (Appendix B), motorcycle noise was 0.7-6.3 dBF (unweighted) greater at tree microphones than base microphones at 15 m in the 2kHz frequency band. We also found that motorcycle noise energy decreased less at tree microphones than at base microphones as stimulus distance increased. At 60-m, motorcycle noise was 9.4-16.4 dBF (unweighted) greater at tree microphones than base microphones at the same frequency for the same motorcycles (Figures B-

2, B-4 and B-6, Appendix B). We selected one-third-octave band levels at a frequency of 2kHz for this comparison based on increased hearing sensitivity of owls within this range (Trainer 1946, Konishi 1973).

Motorcycle Noise Comparisons

The following motorcycle comparisons relate to noise levels and frequency spectra recorded during testing in April 2000 and do not include data from the November enduro event. We could not make the same comparisons for data from the enduro event because we did not have individual motorcycle information such as make and model.

We observed that noise level and frequency spectra varied by motorcycle type. A detailed noise comparison by motorcycle type is listed in Table A-1 (Appendix A). During testing on 24 April, we observed that the 200 cc motorcycle had the highest noise level of the six motorcycles tested at 60 m on the straight, inclined course with a horizontal tree microphone placement followed by the 350, 300, 400, 620 and 100 cc motorcycles. On the curved, horizontal course with a horizontal microphone placement, the 350 cc motorcycle had the highest noise level at 60 m, followed by the 200, 300, 620, 400 and 100 cc motorcycles. On 25 April, we were only able to test three motorcycle types, a 300 cc and two 400 cc motorcycles (a 1997 and 1999 model; Table 1). On a straight, slightly inclined trail with a downslope tree microphone placement (M5/M2 Big Sullivan Road junction), we observed that the 300 cc motorcycle registered the highest noise level at 60 m, followed by the 1999 and 1997 models of the 400 cc motorcycle. Along a straight, horizontal trail with an upslope tree microphone placement (Miner Ridge Road), we observed that the 300 cc motorcycle again registered the highest noise level, but that the 400 cc 1997 model motorcycle was louder than the 1999 model. These data suggest that motorcycles with lower cubic centimeter displacement (i.e., 200, 300 and 350 cc motorcycles) register higher noise levels and have more noise energy in the middle frequency range than motorcycles with higher displacement rates (i.e., 400 and 620 cc motorcycles) over similar distances.

We then examined the frequency spectral data for these motorcycles across a range of distances. We found that the 200 cc motorcycle had the greatest amount of noise energy in the middle frequency range of all of the motorcycles tested (1-4kHz), followed by the 350, 300, 400, 100 and 620 cc motorcycles (Figures B-7 to B-9, Appendix B). The 100 and 620 cc motorcycles had substantially lower noise energy levels in the middle frequency range than the other motorcycles tested. We also found a large overlap in the lower portion of the frequency range (13-200 Hz). These patterns basically held as distance increased to 60 m, except that the 350 cc motorcycle lost less energy in the middle frequency range over the same distance than the 300 and 400 cc motorcycles. It is important to note that having a similar noise level does not necessarily translate into equivalent energy distribution across the frequency spectrum. As an example, when we examined the 620 and 300 cc motorcycles at 60 m (M5/M30 heliport; tree microphones), we found that even though both motorcycles had the same flat maximum 1-Sec LEQ (67.5 dBF; Table A-1, Appendix A), the 300 cc motorcycle had substantially more noise energy in the middle frequency range than the 620 cc motorcycle. This translated into an 11.2 dBO difference between 300 cc motorcycles (78.1 dBO {64.8 dBA}) and 620 cc motorcycles (67.9 dBO {54.3 dBA}) at 2kHz during this 60-m test (Figure B-9, Appendix B).

Trail Slope

Motorcycle noise levels varied by slope. Based on the different slope scenarios tested during the enduro event, we found that motorcycles on steeply inclined trails (> 16° slope) registered the highest noise levels at 60-90 m distances, followed by horizontal (0° slope) and moderately inclined trails (9-16° slope; Table A-2, Appendix A). For the steeply inclined trail, we used the 90 m distance because it was comparable to the other sites in noise level and because a 60 m distance was not recorded at that site. We found that the above pattern held when we examined mean noise levels (i.e., L_{50}) for sites that had comparable data. The steeply inclined trail registered a mean noise level 67.8 dBO (57.4 dBA) at 90 m compared with 63.5 dBO (54.7 dBA) for a horizontal trail and 56.2 dBO (47.5 dBA) for a moderately inclined trail both at 60 m distances. We observed similar patterns when we compared L_{01} and L_{10} levels for these three

slope scenarios (Table A-3, Appendix A)..

Noise Source Comparison

We compared the noise level and frequency spectra of individual and group motorcycle passes with chainsaw noise. Chainsaw noise was only recorded at base microphones during a previous study on MSOs (Delaney et al. 1999; Figure B-10). Based on previous MSO response to chainsaw noise data, we attempted to gauge how spotted owls may respond to motorcycle activity at the levels tested. Chainsaw noise data only represent noise levels and energy distribution for one chainsaw run for 5 minutes, interspersed with alternating 10 second idle and revving periods (Delaney et al. 1999). We only compared the maximum 1-sec LEQ data for both motorcycles and chainsaws. Chainsaw noise and frequency spectra could not be directly compared with motorcycles recorded during the enduro event because chainsaw noise was recorded only at base microphones and enduro noise data were recorded only at tree microphones. Indirectly though, we could compare enduro noise levels by extrapolating noise from tree microphones to base microphones from data recorded in April 2000. This provided us with data that we could compare with MSO response data from chainsaw testing. We could directly compare individual motorcycle noise spectra from data collected in April because those data were recorded at tree and base microphones.

Individual Motorcycles versus Chainsaws

Typical chainsaw noise at 15 m had a maximum 1-sec LEQ of 90.5 dBO (77.8 dBA). Only one of the six motorcycles tested (200 cc motorcycle) at the M5/M30 site on 24 April 2000 had a higher noise level (94.4 dBO {84.5 dBA}) and had more noise energy in the middle frequency range than chainsaws (Table A-1, Appendix A; Figure B-11, Appendix B). The 200 cc motorcycle had a maximum 1-sec LEQ of 78.5 dBO (67.3 dBA) which was comparable with chainsaw noise levels at 30 m (78.2 dBO {65.4 dBA}). Chainsaws had more noise energy in the middle frequency range than all motorcycles tested at 30 m (Figure B-12). At 60 m, chainsaw

noise was louder (70.7 dBO {57.1 dBA}; Table A-1) and had more noise energy in the 2-4kHz frequency range than all six motorcycles tested (Figure B-13).

Group Motorcycles versus Chainsaws

A moderately inclined group motorcycle pass (same motorcycles as individual tests; base microphones) recorded at the M5/M30 heliport site registered a maximum 1-sec LEQ of 64.3 dBO (51.5 dBA) compared with 70.7 dBO (57.1 dBA) for a typical chainsaw run at 60 m. Chainsaws also had more noise energy in the middle frequency range than this group motorcycle event at 60 m (Figure B-14, Appendix B). A horizontal group motorcycle pass (same motorcycles as above; base microphones) recorded at the M5/M20 site registered a maximum 1-sec LEQ of 75.9 dBO (62.3 dBA). The frequency spectrum for this comparison shows that a typical chainsaw had less noise energy in the middle frequency range than this group motorcycle event, particular in the 1-2.5KHz area, but were comparable at frequencies > 2.5kHz (Figure B-15, Appendix B). The three motorcycles tested as a group (300 cc and both 400 cc; 25 April 2000) on a straight, slightly inclined trail with a downslope microphone (near M5/M2 Big Sullivan Ridge junction) registered 70.9 dBO (57.5 dBA), while the same motorcycles registered 75.8 dBO (63.5 dBA) on a straight, horizontal trail with a upslope microphone (Miner Ridge Road). The frequency spectrum for group motorcycles along the moderately inclined trail were comparable to a typical chainsaw (Figure B-16), while the same motorcycles on a horizontal trail had greater noise energy in the middle frequency range than the chainsaw (Figure B-17).

DISCUSSION

There are a number of factors that need to be taken into account when examining the effects of motorcycle noise on animals. For motorcycle noise, these can include: noise level and frequency distribution, stimulus distance and duration, motorcycle type and condition, frequency of noise events, driver aggressiveness, daily and seasonal patterns of noise events, number of motorcycles per group, trail slope, road conditions and microphone position relative to the noise source. For animals, these can include: hearing sensitivity, mated status, breeding status, nesting phase, time of day, fecundity, nest attentiveness, prey delivery rate, current behavior or activity and animal location relative to the noise source. During this initial pilot study we examined the importance of stimulus distance, noise level and frequency distribution, trail slope, motorcycle type, individual versus group motorcycle noise levels and microphone placement on the potential response behavior of NSOs to motorcycle activity.

Microphone Placement

An animal's location relative to a noise source can have a significant effect on the amount of noise (i.e., noise level and duration) that the animal receives. We used microphone location as a surrogate for owl location during this study. We found that motorcycle noise varied substantially depending on the location of the receiving microphone. Motorcycle noise recorded at tree microphones was consistently louder than base microphones over similar distances, regardless of motorcycle type. This has important consequences when we consider nest height (mean nest height 24.3 m; LaHaye and Gutierrez 1999) relative to the surrounding trails. Due to their elevated nests, spotted owls have the potential to hear motorcycle noise longer than at the base of the tree. It is also important to consider nest type when determining potential noise disturbance impacts. NSOs are known to nest in cavities. LaHaye and Gutierrez (1999) found that cavity nests accounted for 20% of the nest types used by spotted owls in northern California. Noise levels recorded in cavity nests are significantly louder than noise levels at the base of nest trees (Delaney et al. 2000). Delaney et al. (2000) also found that nest cavities acted as sound

resonators, emphasizing specific portions of the frequency band and that this affect varied by individual tree. No research to date has studied differences in noise levels between spotted owl nest types.

There are two main reasons why noise levels are louder at tree microphones than base microphones. The first is that base microphones lose more noise energy than tree microphones due to ground absorption. Absorption is the loss or dissipation of noise energy in passing through a material or on striking a surface (Embleton 1982). Softer, rougher surfaces, like the forest floor, will absorb more noise energy than smoother, harder surfaces such as water. Wiener and Keast (1959) reported that noise levels were reduced by up to 10 dB per 100 m at 2kHz across softer ground surfaces. Secondly, the reflection of noise off the ground can result in "the ground effect". When the source and the receiver are both close to the ground, as was the case for motorcycles and base microphones, the noise wave reflected from the ground may interfere with the direct noise wave from the noise source to the microphone reducing the noise level at the receiver (Wiener and Keast 1959)

Motorcycle Noise Comparison

We observed that 200 and 350 cc motorcycles registered the highest noise levels and had the most noise energy in the middle frequency range of the motorcycles tested at 15-60 m distances, followed by 300, 400, 100 and 620 cc motorcycles. Hearing sensitivity studies report that owls hear best in the middle frequency range and that owl hearing is greatly reduced in the lower and upper portions of the frequency spectrum (Trainer 1946, Konishi 1973). Based on these findings, our data suggest that owls would elicit increased behavioral responses towards 200 and 350 cc motorcycles followed by 300, 400, 100 and 620 cc motorcycles. We believe that the 100 cc motorcycle would have registered higher noise levels and been more comparable with other motorcycles if it was driven more aggressively by a more experienced rider. However, typically more experienced, aggressive riders will likely be on larger motorcycles (pers. obs.). Driver experience and their associated aggressiveness in riding a trail can substantially affect resulting

noise level and how noise is distributed across the frequency spectrum.

The noise level and frequency distribution of a stimulus event has important consequences on its propagation across the landscape. Over long distances, lower frequency noise events are attenuated less than higher frequency events (Embleton 1982). Over shorter distances such attenuation may take place, but on a more limited scale. This was evident in our examination of how different motorcycle types decreased in noise level with distance. In both of the examples we provided, the 350 cc motorcycle registered the least difference in noise level over distance, while higher frequency motorcycles, such as the 100 and 200 cc, had greater reductions in noise level over this same distance. This reduction in noise level for higher frequency motorcycles is not as important over shorter distances because noise levels are still quite high, but has a greater effect over longer distances.

Trail Slope

Our data suggest that motorcycle noise on steeply inclined trails would elicit the greatest behavioral responses by spotted owls, followed by horizontal and moderately inclined trails. We observed that motorcycles traveling on steeply inclined trails registered the highest noise levels, followed by motorcycles on horizontal and moderately inclined trails. These data suggest that trail slope may influence trail usage by motorcycle riders. The steeper the trail, the greater the power required to traverse along the trail which leads to louder noise signatures. It also appears as if trail shape, i.e., straight or curved, influences trail usage, which in turn influences motorcycle noise levels. Although we did not experimentally test this variable, we observed that riders were more aggressive driving along straight trails than curved trails, regardless of slope. The length of the straight or curved trail section may also influence how riders utilize the trail.

During the fall enduro event, we observed that the distance between riders was reduced on steeply inclined trails versus horizontal and moderately inclined trails. This could have attributed to the higher noise levels that we recorded because motorcycles were grouped closer together and

therefore produced a greater noise profile. We also noticed that rider spacing varied along the enduro course. Riders were more evenly spaced in their designated groups early in the event as they passed our first two test sites in the first 15 km (9.3 miles), but that spacing in and between groups was reduced as the riders traveled past our third test site at around 20 km (12.4 miles) along the course on a steeply inclined trail. At our fourth site, which was approximately 48 km (30 miles) along the 96.6 km (60 mile) course, rider spacing in and between groups had increased. We also noticed that motorcycle riders tended to slow down or speed up in order to adjust their arrival times as they approached check points along the enduro course. This can have important consequences on the noise level and duration of noise events in areas at or near check point locations. Based on these findings, our data suggest that motorcycle noise along steeply inclined trails would elicit the greatest behavioral responses by spotted owls, followed by horizontal and moderately inclined trails.

Noise Source Comparison

Motorcycles versus Chainsaws

We are not aware of any studies that have compared chainsaw and motorcycle noise data for the expressed purpose of relating potential animal response. Only one study to date has experimentally tested spotted owl response to chainsaw noise (Delaney et al. 1999). Delaney et al. (1999) reported that MSOs did not flush when the LEQ level for chain saws was ≤ 59 dBO (46 dBA) and chainsaws were > 105 m distant. When we compared noise levels and frequency spectra for motorcycles and chainsaws we found they were comparable at similar distances, though there was some variation according to motorcycle type, number of motorcycles per event and trail slope. Chainsaws registered higher noise levels and more noise energy distributed in the middle frequency range than most of the individual motorcycles tested on moderately inclined and horizontal trails. This does not appear to be the case for motorcycle noise along steeply inclined trails. Extrapolated noise data from the enduro event suggests that individual motorcycles could have higher noise levels than chainsaws along steeply inclined trails.

When we examined group motorcycle noise data versus chainsaw data, we found that most of the group motorcycles events had higher noise levels and more noise energy distributed in the middle frequency range than chainsaws at comparable distances. It is important to note that group motorcycle events, namely enduro events, have the potential for many noise events over an extended period of time. It is possible that group motorcycle activity could elicit greater response measures than chainsaw testing. Overall, we do not anticipate that NSOs would flush in response to motorcycle activity > 180 m from an owl's location based on MSO response to chainsaw noise levels. At distances < 180 m, motorcycle noise levels did surpass the flush threshold established for MSOs. Further research is needed to experimentally test NSO response directly to motorcycle activity to better develop this distance and noise threshold relationship.

MANAGEMENT IMPLICATIONS

This research provides detailed noise and spectral information on motorcycle activity that can be used by natural resource managers and researchers to develop a full scale study to address the potential effects of motorcycle noise on spotted owls. Due to the inability to reliably locate spotted owls during the 2000 field season, we were unable to develop dose-response threshold relationships for quantifying Northern Spotted Owl responses to variations in motorcycle noise levels and stimulus distances. We therefore are unable to make any definitive recommendations on the effects of motorcycle noise on Northern Spotted Owls. The following data are offered as a list of recommended items that need to be examined more closely in conducting such a study.

1) Distance and Noise Threshold: We do not anticipate that Northern Spotted Owls would flush in response to motorcycle activity > 180 m from an owl's location based on prior noise research conducted on Mexican Spotted Owls with chainsaw noise. At distances < 180 m, motorcycle noise levels did surpass the flush threshold established for Mexican Spotted Owls. Further research is needed to experimentally test Northern Spotted Owl response to motorcycle activity to better develop this distance and noise threshold relationship;
2) Trail slope and shape: Our data indicate that motorcycles passing by on steep (>16° slope) inclined trails may elicit the greatest behavioral response by spotted owls, followed by motorcycles on horizontal (0° slope) and moderately (9-16° slope) inclined trails. Traffic on straight trails may also elicit greater spotted owl response behavior than curved trails;
3) Microphone Placement: Motorcycle noise levels at microphones placed 10 m above ground level in trees was louder and lost less noise energy over distance than microphones placed at the base of the same trees. Owls at nest or roost locations could be receiving substantially higher noise levels than those recorded at base microphones. We recommend that researchers record motorcycle events at actual owl nest or roost locations before or after the nesting season to determine the exact noise levels, which can be used

to extrapolate nesting season data from base microphones to tree locations;

4) Nest type: Cavity nests may receive higher noise levels than other external structure nest types due to a resonating effect within the cavity itself;
5) Motorcycle type: Motorcycles with higher frequency noise signatures (e.g., 200 cc motorcycles) are potentially more disturbing to spotted owls than lower frequency motorcycles (e.g., 400 cc motorcycles;
6) Driver aggressiveness: Driver aggressiveness in riding a course can have a substantial effect on motorcycle noise level and noise energy distribution;
7) Motorcycle use: We recommend that enduro check points and fuel stops not be located near owl locations because of the potential increases in noise level and duration associated with such activity.

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Appendix A

Table A-1. Comparison of noise level by stimulus distance and motorcycle type at various locations and riding scenarios on the Mendocino National Forest on 24-25 April 2000.

Location	Motorcycle Type	Bike Position	Microphone Position	Stimulus Distance	Maximum 1-Sec LEQ Flat	A	Owl
M5/M30 heliport	620 cc. Street Legal	Incline	Tree/Horizontal	15	76.3	66.6	79.6
M5/M30 heliport	620 cc. Street Legal	Incline	Base/Horizontal	15	74.1	61.9	74.5
M5/M30 heliport	620 cc. Street Legal	Incline	Tree/Horizontal	30	73.9	61.7	74.1
M5/M30 heliport	620 cc. Street Legal	Incline	Base/Horizontal	30	70.4	53.4	64.4
M5/M30 heliport	620 cc. Street Legal	Incline	Tree/Horizontal	60	67.5	54.3	67.9
M5/M30 heliport	620 cc. Street Legal	Incline	Base/Horizontal	60	64.4	43.2	52.0
M5/M30 heliport	300 cc. 2 Stroke	Incline	Tree/Horizontal	15	81.7	79.6	91.7
M5/M30 heliport	300 cc. 2 Stroke	Incline	Base/Horizontal	15	76.4	71.3	84.5
M5/M30 heliport	300 cc. 2 Stroke	Incline	Tree/Horizontal	30	73.1	70.6	82.8
M5/M30 heliport	300 cc. 2 Stroke	Incline	Base/Horizontal	30	68.0	61.9	75.0
M5/M30 heliport	300 cc. 2 Stroke	Incline	Tree/Horizontal	60	67.5	64.8	78.1
M5/M30 heliport	300 cc. 2 Stroke	Incline	Base/Horizontal	60	58.6	48.9	62.6
M5/M30 heliport	350 cc. 4 Stroke	Incline	Tree/Horizontal	15	83.3	78.6	90.2
M5/M30 heliport	350 cc. 4 Stroke	Incline	Base/Horizontal	15	82.2	74.8	86.5
M5/M30 heliport	350 cc. 4 Stroke	Incline	Tree/Horizontal	30	78.7	75.8	85.3
M5/M30 heliport	350 cc. 4 Stroke	Incline	Base/Horizontal	30	76.3	64.8	76.7
M5/M30 heliport	350 cc. 4 Stroke	Incline	Tree/Horizontal	60	74.8	69.8	82.5
M5/M30 heliport	350 cc. 4 Stroke	Incline	Base/Horizontal	60	69.0	54.5	67.1
M5/M30 heliport	200 cc. 2 Stroke	Incline	Tree/Horizontal	15	89.7	88.2	98.0
M5/M30 heliport	200 cc. 2 Stroke	Incline	Base/Horizontal	15	87.9	84.5	94.4
M5/M30 heliport	200 cc. 2 Stroke	Incline	Tree/Horizontal	30	75.0	74.7	86.8
M5/M30 heliport	200 cc. 2 Stroke	Incline	Base/Horizontal	30	69.5	67.3	78.5
M5/M30 heliport	200 cc. 2 Stroke	Incline	Tree/Horizontal	60	74.5	72.5	84.5
M5/M30 heliport	200 cc. 2 Stroke	Incline	Base/Horizontal	60	65.1	56.1	67.4
M5/M30 heliport	100 cc. 2 Stroke	Incline	Tree/Horizontal	15	74.9	68.1	79.9
M5/M30 heliport	100 cc. 2 Stroke	Incline	Base/Horizontal	15	73.3	65.7	76.8
M5/M30 heliport	100 cc. 2 Stroke	Incline	Tree/Horizontal	30	67.1	56.8	67.6
M5/M30 heliport	100 cc. 2 Stroke	Incline	Base/Horizontal	30	65.1	51.2	59.6
M5/M30 heliport	100 cc. 2 Stroke	Incline	Tree/Horizontal	60	63.8	54.2	62.9
M5/M30 heliport	100 cc. 2 Stroke	Incline	Base/Horizontal	60	60.5	47.2	50.4
M5/M30 heliport	400 cc. 4 Stroke	Incline	Tree/Horizontal	15	82.8	78.7	91.1
M5/M30 heliport	400 cc. 4 Stroke	Incline	Base/Horizontal	15	81.0	75.2	87.5
M5/M30 heliport	400 cc. 4 Stroke	Incline	Tree/Horizontal	30	75.7	67.3	79.7
M5/M30 heliport	400 cc. 4 Stroke	Incline	Base/Horizontal	30	74.4	60.1	71.5
M5/M30 heliport	400 cc. 4 Stroke	Incline	Tree/Horizontal	60	69.2	61.2	73.9
M5/M30 heliport	400 cc. 4 Stroke	Incline	Base/Horizontal	60	65.4	48.9	61.7

Location	Motorcycle Type	Bike Position	Microphone Position	Stimulus Distance	Maximum 1-Sec LEQ Flat	A	Owl
M5/M20 Junction	620 cc, Street Legal	Horizontal	Tree/Horizontal	15	72.7	62.5	74.0
M5/M20 Junction	620 cc, Street Legal	Horizontal	Base/Horizontal	15	69.6	54.1	67.5
M5/M20 Junction	620 cc, Street Legal	Horizontal	Tree/Horizontal	30	68.4	62.3	76.7
M5/M20 Junction	620 cc, Street Legal	Horizontal	Base/Horizontal	30	62.3	51.1	63.8
M5/M20 Junction	620 cc, Street Legal	Horizontal	Tree/Horizontal	60	61.3	53.9	67.9
M5/M20 Junction	620 cc, Street Legal	Horizontal	Base/Horizontal	60	54.8	45.0	56.6
M5/M20 Junction	300 cc, 2 Stroke	Horizontal	Tree/Horizontal	15	68.8	62.5	73.3
M5/M20 Junction	300 cc, 2 Stroke	Horizontal	Base/Horizontal	15	64.4	55.7	63.7
M5/M20 Junction	300 cc, 2 Stroke	Horizontal	Tree/Horizontal	30	65.7	64.8	78.0
M5/M20 Junction	300 cc, 2 Stroke	Horizontal	Base/Horizontal	30	62.6	56.3	68.1
M5/M20 Junction	300 cc, 2 Stroke	Horizontal	Tree/Horizontal	60	64.8	55.3	68.4
M5/M20 Junction	300 cc, 2 Stroke	Horizontal	Base/Horizontal	60	58.2	48.9	61.4
M5/M20 Junction	350 cc, 4 Stroke	Horizontal	Tree/Horizontal	15	79.9	74.6	86.8
M5/M20 Junction	350 cc, 4 Stroke	Horizontal	Base/Horizontal	15	73.7	66.0	77.3
M5/M20 Junction	350 cc, 4 Stroke	Horizontal	Tree/Horizontal	30	76.2	76.1	89.9
M5/M20 Junction	350 cc, 4 Stroke	Horizontal	Base/Horizontal	30	72.6	65.7	79.0
M5/M20 Junction	350 cc, 4 Stroke	Horizontal	Tree/Horizontal	60	70.1	70.1	84.9
M5/M20 Junction	350 cc, 4 Stroke	Horizontal	Base/Horizontal	60	69.0	55.5	68.7
M5/M20 Junction	200 cc, 2 Stroke	Horizontal	Tree/Horizontal	15	74.6	74.4	85.9
M5/M20 Junction	200 cc, 2 Stroke	Horizontal	Base/Horizontal	15	66.3	64.6	77.3
M5/M20 Junction	200 cc, 2 Stroke	Horizontal	Tree/Horizontal	30	73.3	73.9	87.0
M5/M20 Junction	200 cc, 2 Stroke	Horizontal	Base/Horizontal	30	65.0	64.0	76.9
M5/M20 Junction	200 cc, 2 Stroke	Horizontal	Tree/Horizontal	60	65.7	66.4	80.3
M5/M20 Junction	200 cc, 2 Stroke	Horizontal	Base/Horizontal	60	62.3	60.8	73.5
M5/M20 Junction	100 cc, 2 Stroke	Horizontal	Tree/Horizontal	15	68.7	58.1	69.4
M5/M20 Junction	100 cc, 2 Stroke	Horizontal	Base/Horizontal	15	66.8	51.2	64.4
M5/M20 Junction	100 cc, 2 Stroke	Horizontal	Tree/Horizontal	30	62.4	57.3	70.8
M5/M20 Junction	100 cc, 2 Stroke	Horizontal	Base/Horizontal	30	57.5	46.8	58.2
M5/M20 Junction	100 cc, 2 Stroke	Horizontal	Tree/Horizontal	60	54.8	46.8	60.1
M5/M20 Junction	100 cc, 2 Stroke	Horizontal	Base/Horizontal	60	47.9	38.4	49.0
M5/M20 Junction	400 cc, 4 Stroke	Horizontal	Tree/Horizontal	15	71.5	60.3	72.8
M5/M20 Junction	400 cc, 4 Stroke	Horizontal	Base/Horizontal	15	69.7	55.6	66.9
M5/M20 Junction	400 cc, 4 Stroke	Horizontal	Tree/Horizontal	30	68.3	66.0	80.0
M5/M20 Junction	400 cc, 4 Stroke	Horizontal	Base/Horizontal	30	65.9	54.3	66.8
M5/M20 Junction	400 cc, 4 Stroke	Horizontal	Tree/Horizontal	60	60.7	53.0	66.8
M5/M20 Junction	400 cc, 4 Stroke	Horizontal	Base/Horizontal	60	54.1	44.6	57.2
M5/M2 Big Sullivan Ridge	300 cc, 2 Stroke	Incline	Tree/Downslope	30	74.6	75.0	88.4
M5/M2 Big Sullivan Ridge	300 cc, 2 Stroke	Incline	Base/Downslope	30	68.0	64.4	77.0
M5/M2 Big Sullivan Ridge	300 cc, 2 Stroke	Incline	Tree/Downslope	60	61.1	61.0	74.9

Location	Motorcycle Type	Bike Position	Microphone Position	Stimulus Distance	Maximum 1-Sec LEQ Flat	A	Owl
M5/M2 Big Sullivan Ridge	300 cc, 2 Stroke	Incline	Base/Downslope	60	58.3	54.0	67.5
M5/M2 Big Sullivan Ridge	300 cc, 2 Stroke	Incline	Tree/Downslope	120	54.2	54.1	68.6
M5/M2 Big Sullivan Ridge	300 cc, 2 Stroke	Incline	Base/Downslope	120	54.0	48.7	62.3
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1999	Incline	Tree/Downslope	30	73.8	71.2	87.4
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1999	Incline	Base/Downslope	30	73.6	63.1	74.9
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1999	Incline	Tree/Downslope	60	66.3	58.3	72.1
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1999	Incline	Base/Downslope	60	58.9	50.7	63.2
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1999	Incline	Tree/Downslope	120	59.2	54.0	68.0
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1999	Incline	Base/Downslope	120	54.9	48.0	61.0
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1997	Incline	Tree/Downslope	30	73.9	70.3	85.9
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1997	Incline	Base/Downslope	30	71.7	61.7	73.9
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1997	Incline	Tree/Downslope	60	64.0	56.6	69.6
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1997	Incline	Base/Downslope	60	57.7	49.2	61.7
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1997	Incline	Tree/Downslope	120	60.4	52.1	66.6
M5/M2 Big Sullivan Ridge	400 cc, 4 Stroke 1997	Incline	Base/Downslope	120	52.8	47.8	60.8
Miner Ridge Road	300 cc, 2 Stroke	Horizontal	Tree/Upslope	30	71.9	72.1	85.9
Miner Ridge Road	300 cc, 2 Stroke	Horizontal	Base/Upslope	30	71.5	70.7	84.0
Miner Ridge Road	400 cc, 4 Stroke 1999	Horizontal	Tree/Upslope	30	68.5	62.0	75.9
Miner Ridge Road	400 cc, 4 Stroke 1999	Horizontal	Base/Upslope	30	62.4	61.3	74.4
Miner Ridge Road	400 cc, 4 Stroke 1997	Horizontal	Tree/Upslope	30	72.8	66.9	80.3
Miner Ridge Road	400 cc, 4 Stroke 1997	Horizontal	Base/Upslope	30	67.3	66.7	79.2
Miner Ridge Road	300 cc, 2 Stroke	Horizontal	Tree/Upslope	60	62.4	61.7	75.1
Miner Ridge Road	300 cc, 2 Stroke	Horizontal	Base/Upslope	60	62.1	60.4	73.8
Miner Ridge Road	400 cc, 4 Stroke 1999	Horizontal	Tree/Upslope	60	62.5	55.2	68.7
Miner Ridge Road	400 cc, 4 Stroke 1999	Horizontal	Base/Upslope	60	55.2	54.7	64.9
Miner Ridge Road	400 cc, 4 Stroke 1997	Horizontal	Tree/Upslope	60	62.9	61.6	74.2
Miner Ridge Road	400 cc, 4 Stroke 1997	Horizontal	Base/Upslope	60	55.7	45.5	56.2

Table A-2. Number, distance and noise level for motorcycles recorded during a fall enduro event on the Mendocino National Forest on 19 November 2000.

Location	Stimulus Distance (m)	Number of Noise Events	Noise Levels, Max. 1-Sec LEQ (dB) Unweighted	"A" weighted	Owl weighted	Typical Ambient LEQ (dB) "A" weighted
M10/M34 junction	10-30	68	76.0 - 95.8	71.2 - 88.6	83.0 - 98.4	37
M34/17N63 junction	60	53	67.1 - 87.8	54.9 - 84.1	68.3 - 95.0	36
M32/17N12 junction	30	75	70.0 - 91.0	63.4 - 85.8	74.3 - 96.9	34
M32/17N12 junction	60	82	62.1 - 83.2	54.0 - 78.8	55.1 - 89.3	34
M32/17N12 junction	90	31	60.1 - 78.4	46.4 - 73.3	50.1 - 82.8	34
M36/17N63 junction	90	50	66.6 - 88.8	60.3 - 84.8	71.5 - 96.6	32
M36/17N63 junction	120	50	61.4 - 74.3	54.3 - 68.4	63.8 - 80.6	32
M36/17N63 junction	180	44	58.2 - 70.0	45.2 - 62.3	60.7 - 71.1	32

Table A-3. Noise pressure levels and distances for motorcycles recorded during an enduro event on the Mendocino National Forest on 19 November 2000.

Location	Stimulus Distance (m)	Slope (%)	Noise Levels, 1-Sec LEQ (dB) Unweighted	"A" weighted	Owl weighted	Noise Pressure Level
M10/M34 Junction	10-30	9-12	95.8	88.6	98.4	Maximum
M10/M34 Junction	10-30	9-12	89.9	84.0	93.0	L01
M10/M34 Junction	10-30	9-12	82.7	74.4	83.5	L10
M10/M34 Junction	10-30	9-12	71.4	60.9	70.6	L50
M34/17N63 Junction	60	0	87.8	84.1	95.0	Maximum
M34/17N63 Junction	60	0	79.9	74.3	86.0	L01
M34/17N63 Junction	60	0	73.3	67.2	78.5	L10
M34/17N63 Junction	60	0	64.1	54.7	63.5	L50
M32/17N12 Junction	30	12-14	91.0	85.8	96.9	Maximum
M32/17N12 Junction	30	12-14	82.5	78.6	90.6	L01
M32/17N12 Junction	30	12-14	73.9	68.3	79.8	L10
M32/17N12 Junction	30	12-14	58.0	48.7	57.6	L50
M32/17N12 Junction	60	12-14	83.2	78.8	89.3	Maximum
M32/17N12 Junction	60	12-14	75.0	70.6	84.2	L01
M32/17N12 Junction	60	12-14	67.8	62.1	73.2	L10
M32/17N12 Junction	60	12-14	56.6	47.5	56.2	L50
M32/17N12 Junction	90	9-10	78.4	73.3	82.8	Maximum
M32/17N12 Junction	90	9-10	72.8	67.3	76.9	L01
M32/17N12 Junction	90	9-10	66.4	59.8	69.4	L10
M32/17N12 Junction	90	9-10	54.6	44.2	51.3	L50
M36/17N63 Junction	90	18-20	84.7	80.4	93.0	Maximum
M36/17N63 Junction	90	18-20	81.0	76.0	87.9	L01
M36/17N63 Junction	90	18-20	76.6	71.1	82.5	L10
M36/17N63 Junction	90	18-20	64.6	57.4	67.8	L50
M36/17N63 Junction	120	18-20	74.3	67.8	80.6	Maximum
M36/17N63 Junction	120	18-20	70.3	64.4	75.8	L01
M36/17N63 Junction	120	18-20	65.7	59.6	70.0	L10
M36/17N63 Junction	120	18-20	55.8	47.7	57.3	L50
M36/17N63 Junction	180	18-20	70.0	62.3	72.6	Maximum
M36/17N63 Junction	180	18-20	65.8	58.7	68.5	L01
M36/17N63 Junction	180	18-20	62.0	54.3	64.2	L10
M36/17N63 Junction	180	18-20	56.7	47.8	56.7	L50

Appendix B

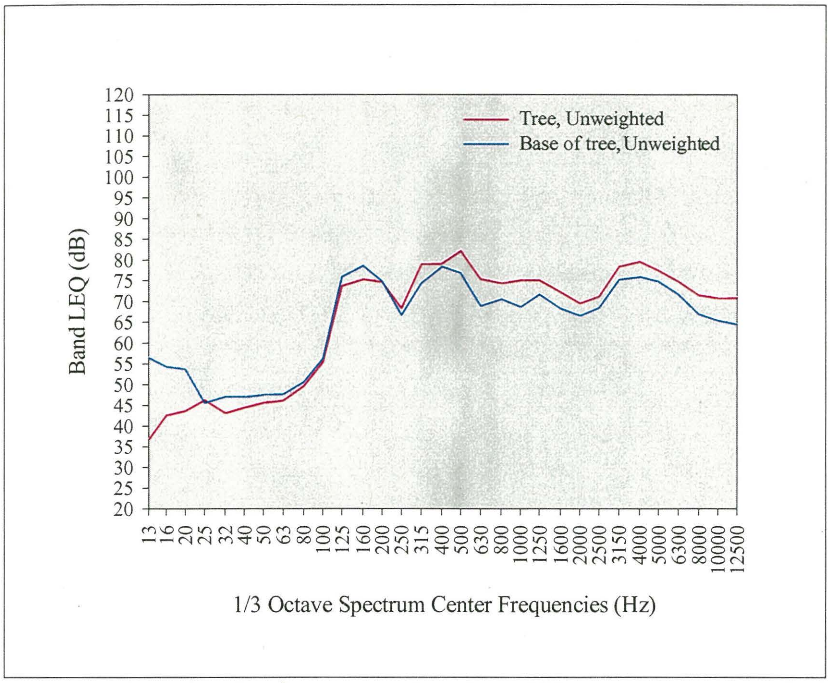

Figure B-1. LEQ weighting comparison for a 200 cc motorcycle (moderately inclined trail with horizontal microphones) between tree and base microphones at 15 m in the Mendocino National Forest in California on 24 April 2000.

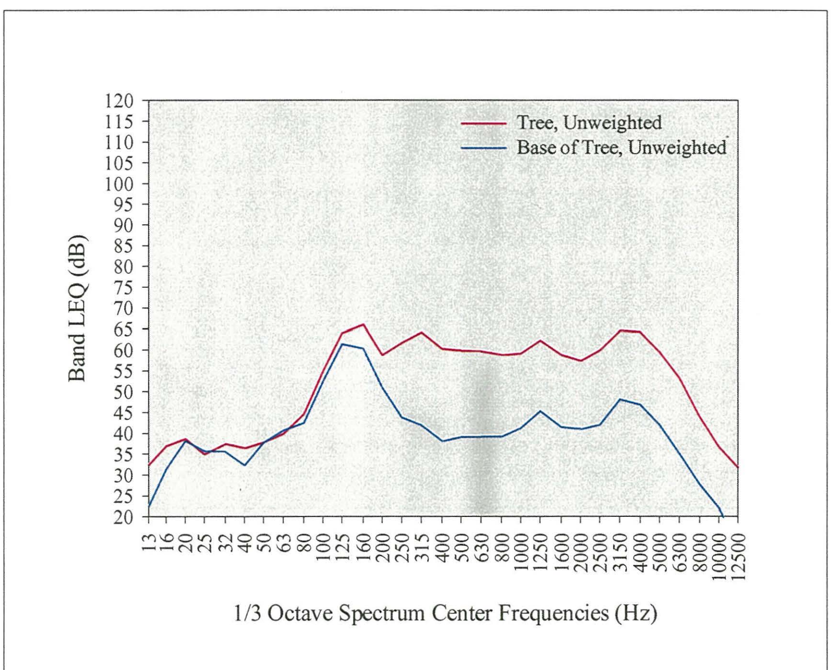

Figure B-2. LEQ weighting comparison for a 200 cc motorcycle (moderately inclined trail with horizontal microphones) between tree and base microphones at 60 m in the Mendocino National Forest in California on 24 April 2000.

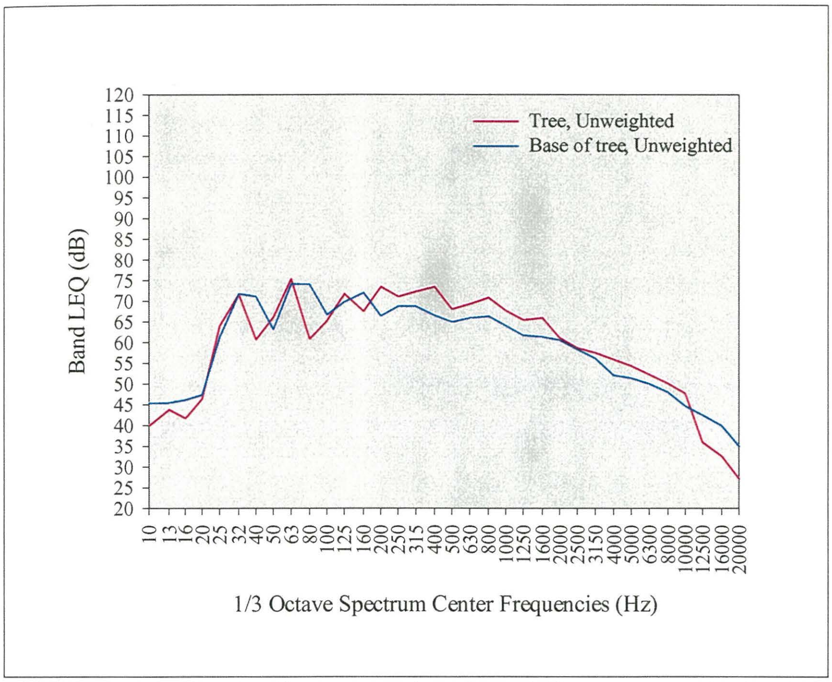

Figure B-3. LEQ weighting comparison for a 350 cc motorcycle (moderately inclined trail with horizontal microphones) between tree and base microphones at 15 m in the Mendocino National Forest in California on 24 April 2000.

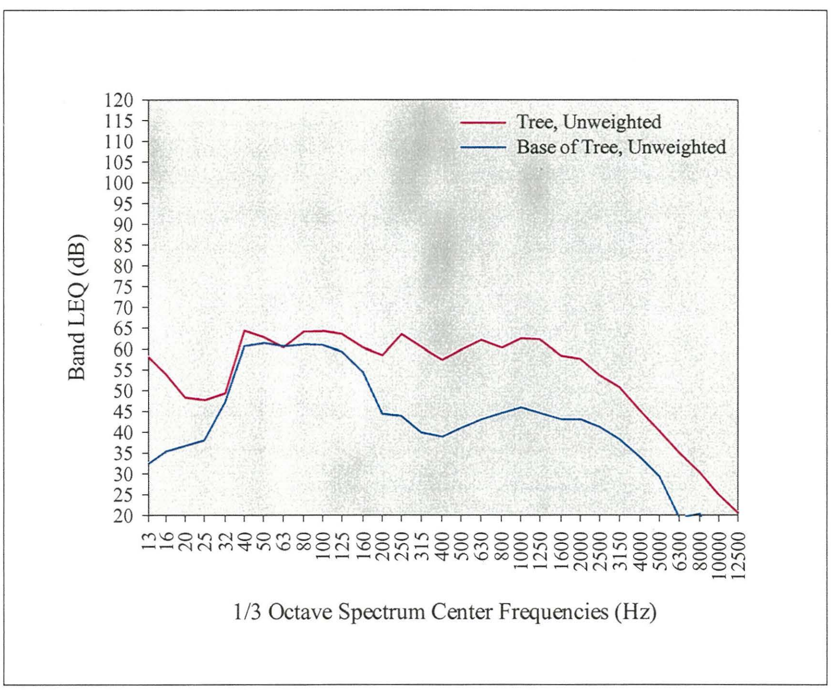

Figure B-4. LEQ weighting comparison for a 350 cc motorcycle (moderately inclined trail with horizontal microphones) between tree and base microphones at 60 m in the Mendocino National Forest in California on 24 April 2000.

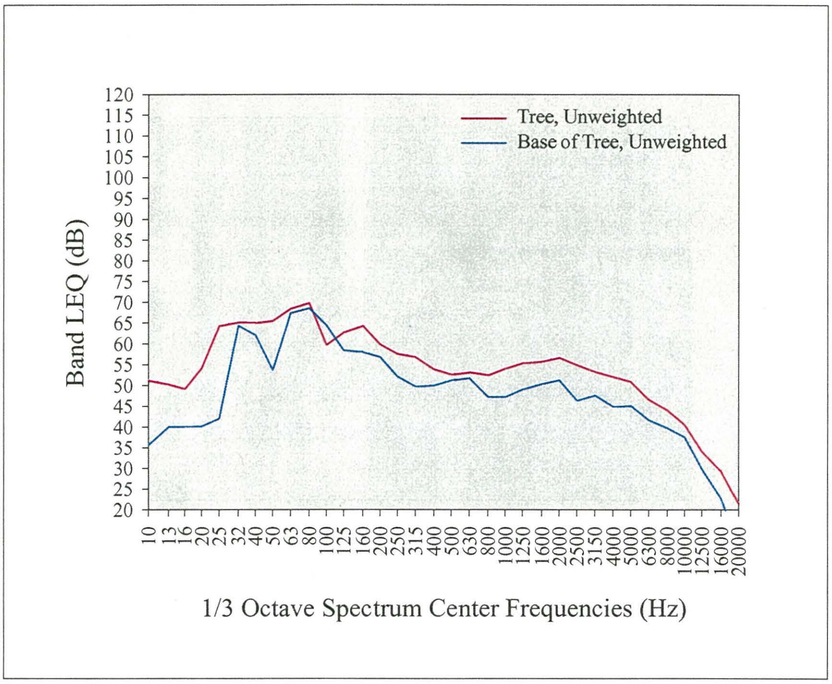

Figure B-5. LEQ weighting comparison for a 620 cc motorcycle (moderately inclined trail with horizontal microphones) between tree and base microphones at 15 m in the Mendocino National Forest in California on 24 April 2000.

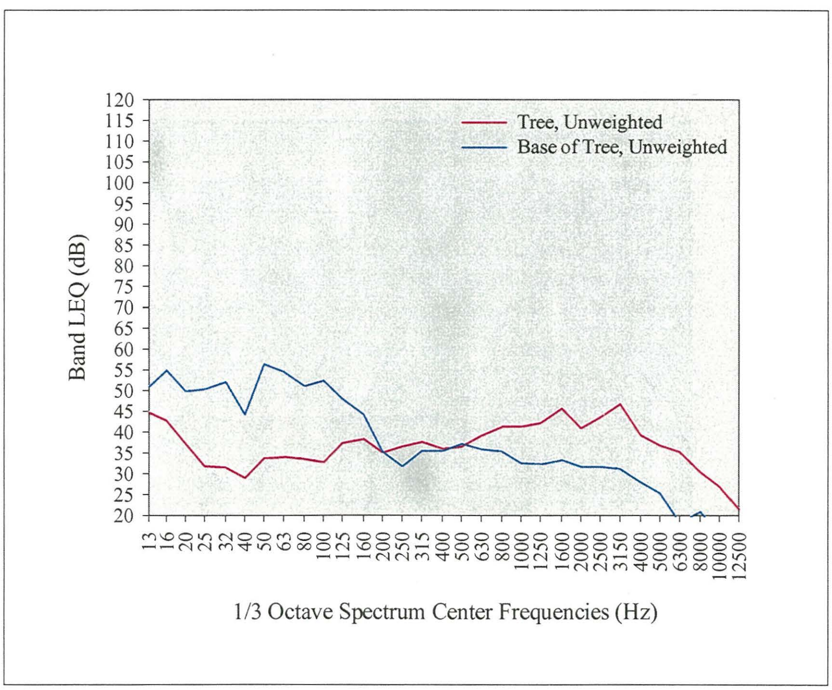

Figure B-6. LEQ weighting comparison for a 620 cc motorcycle (moderately inclined trail with horizontal microphones) between tree and base microphones at 60 m in the Mendocino National Forest in California on 24 April 2000.

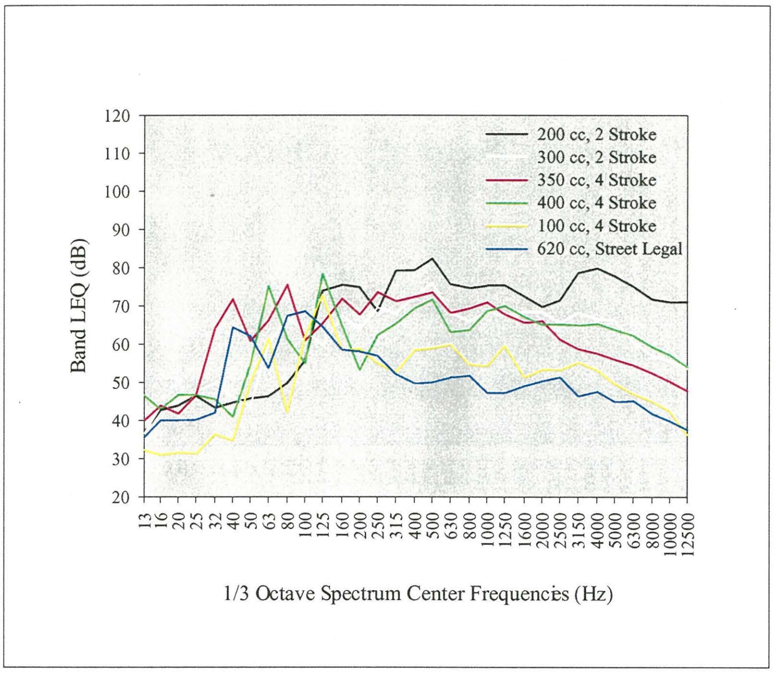

Figure B-7. LEQ comparison of motorcycle types at 15 m (moderately inclined trail with horizontal tree microphones) in the Mendocino National Forest in California on 24 April 2000.

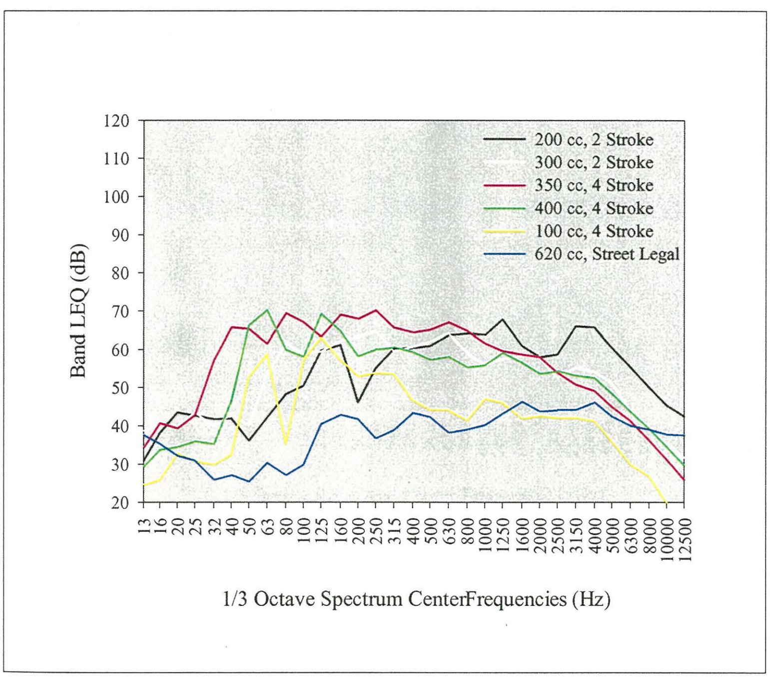

Figure B-8. LEQ comparison of motorcycle types at 30 m (moderately inclined trail with horizontal tree microphones) in the Mendocino National Forest in California on 24 April 2000.

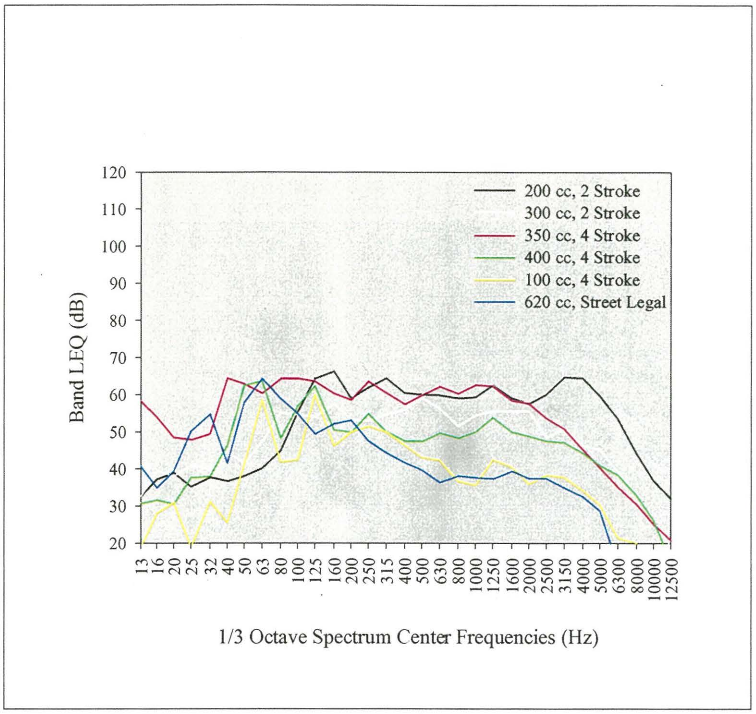

Figure B-9. LEQ comparison of motorcycle types at 60 m (moderately inclined trail with horizontal tree microphones) in the Mendocino National Forest in California on 24 April 2000.

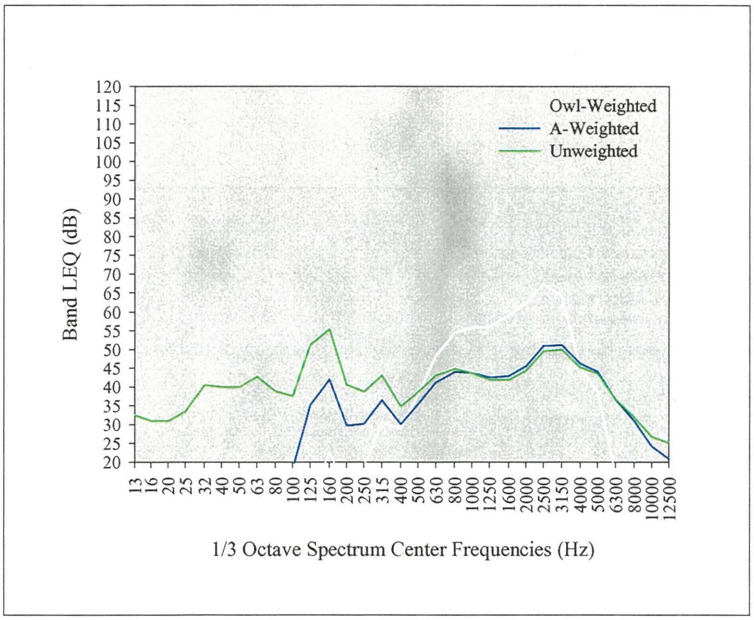

Figure B-10. LEQ comparison of motorcycle types at 60 m (moderately inclined trail with horizontal tree microphones) in the Mendocino National Forest in California on 24 April 2000.

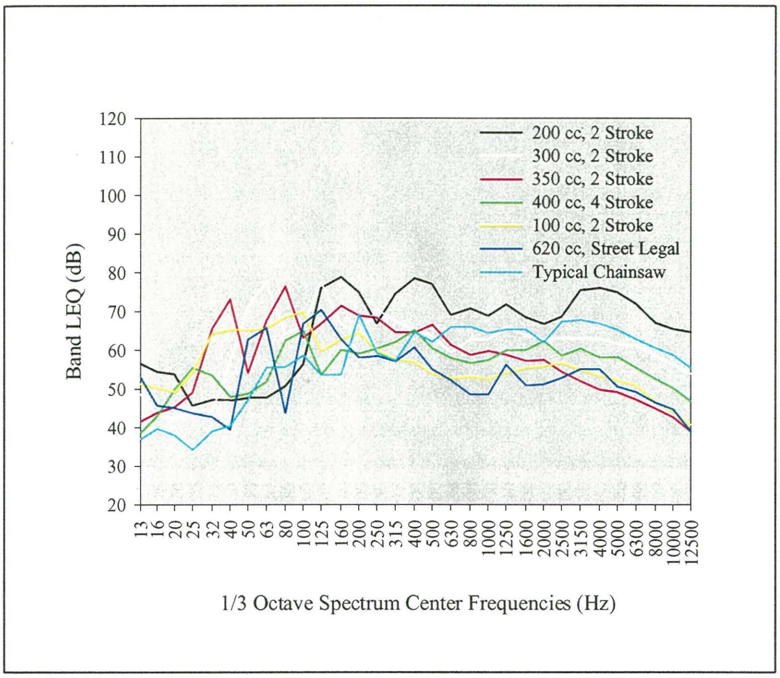

Figure B-11. LEQ comparison of individual motorcycles by type (moderately inclined trail with horizontal base microphones) versus chainsaw noise at 15 m.

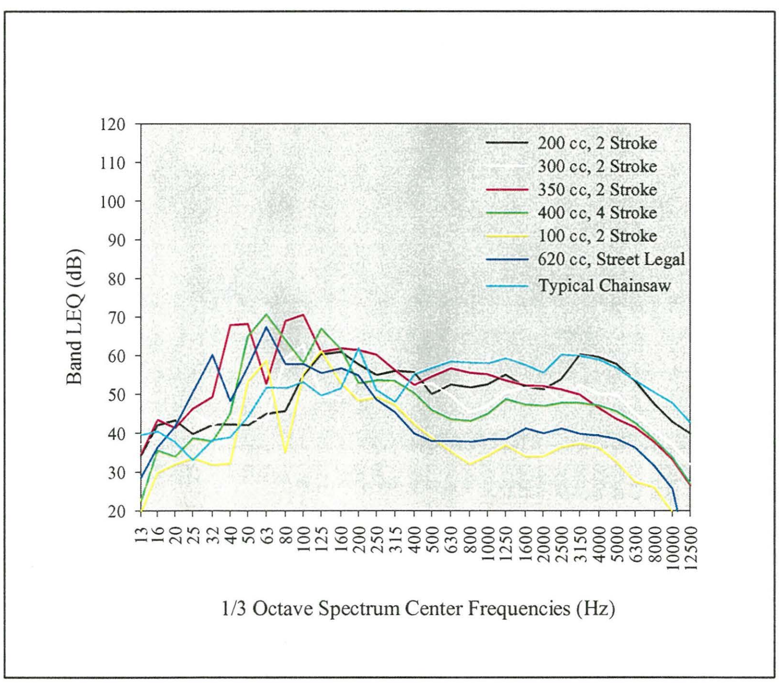

Figure B-12. LEQ comparison of individual motorcycles by type (moderately inclined trail with horizontal base microphones) versus chainsaw noise at 30 m.

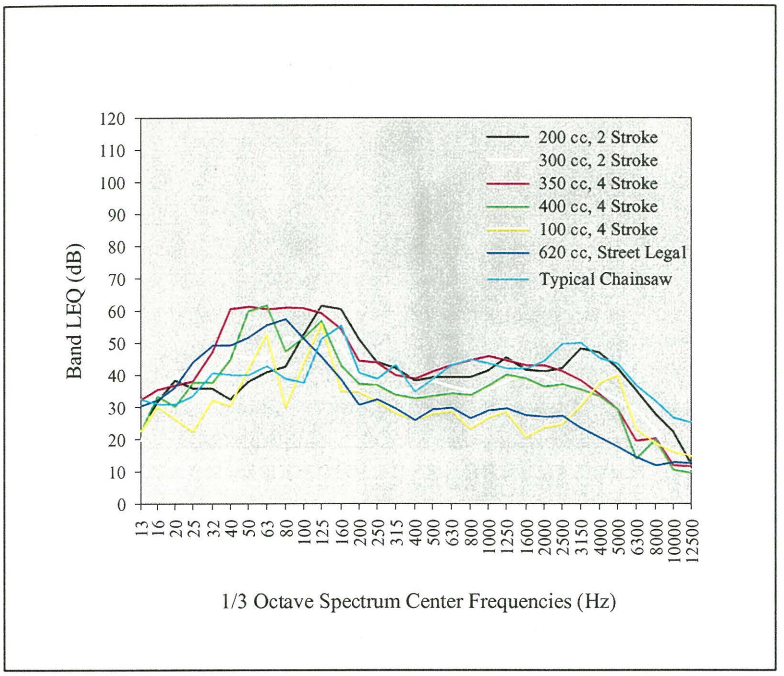

Figure B-13. LEQ comparison of individual motorcycles by type (moderately inclined trail with horizontal base microphones) versus chainsaw noise at 60 m.

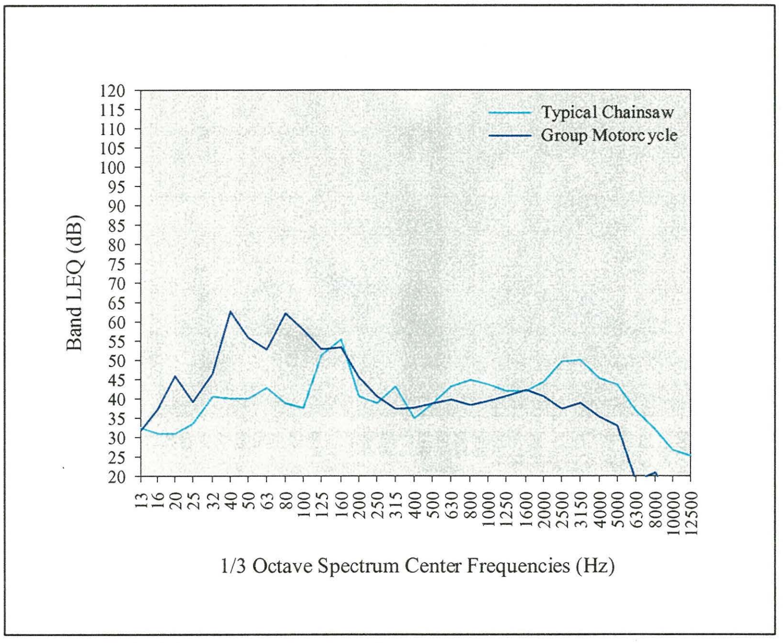

Figure B-14. LEQ comparison of group motorcycles (moderately inclined trail with horizontal microphones) in the Mendocino National Forest on 24 April 2000 versus chainsaw noise at 60 m.

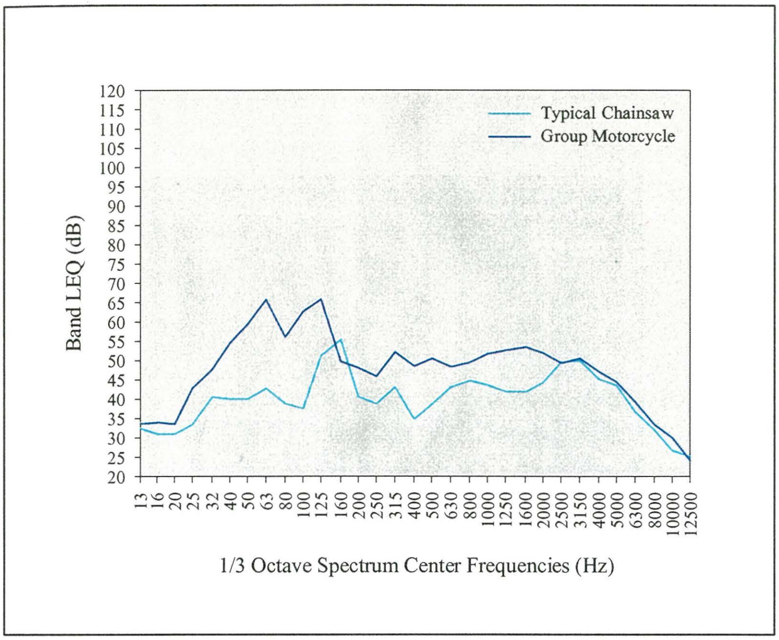

Figure B-15. LEQ comparison of group motorcycles (horizontal trail and microphone) in the Mendocino National Forest on 24 April 2000 versus chainsaw noise at 60 m.

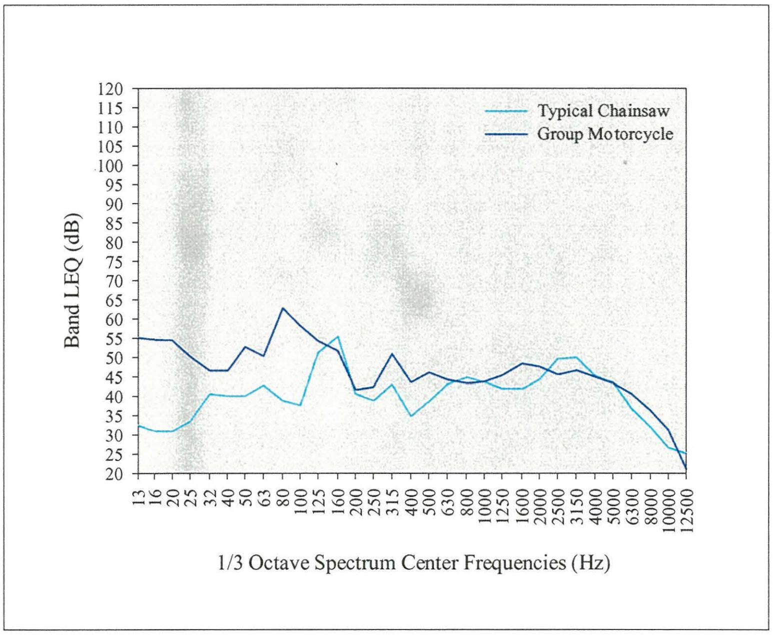

Figure B-16. LEQ comparison of group motorcycles (slightly inclined trail and downslope microphone) in the Mendocino National Forest on 25 April 2000 versus chainsaw noise at 60 m.

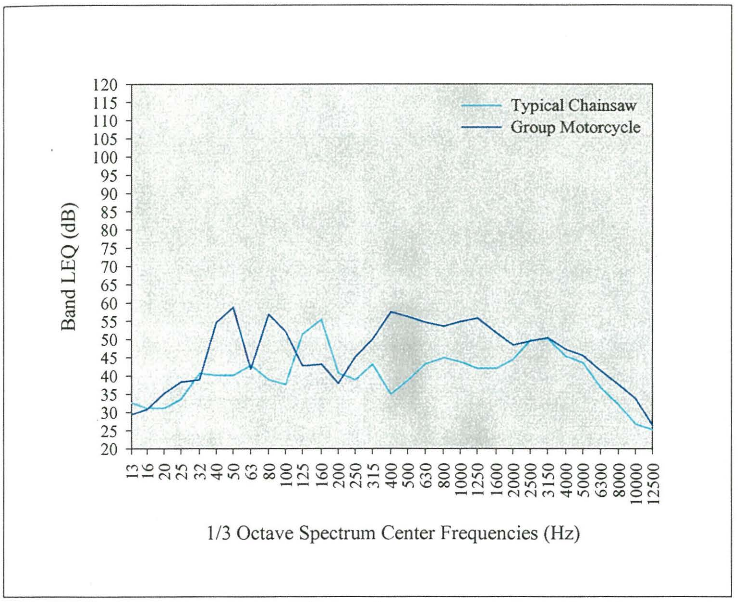

Figure B-17. LEQ comparison of group motorcycles (horizontal trail and upslope microphone) in the Mendocino National Forest On 25 April 2000 versus chainsaw noise at 60 m.